THE NEW TECHNOLOGY OF LARGE SCALE SIMULATOR NETWORKING: IMPLICATIONS FOR MASTERING THE ART OF WARFIGHTING

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ABSTRACT

Advances in several core technologies, particularly local and long haul networking, open up a new area in simulation: Large scale simulator networking (SIMNET). This has important implications for training warfighting skills as well as providing tools for other areas. These are discussed along with a description of new capabilities and future directions.

INTRODUCTION

It appears that the ability to plug together large networks of simulators is well within our grasp. Local area networking technology is established and can be purchased off the shelf for connecting perhaps hundreds of simulators at a given site. Long haul networking technology is maturing rapidly and will provide force-on-force gaming between sites. Microprocessors, the interchangeable muscle on network skeletons, grow in strength and drop in cost with each new generation every couple of years. And a fresh look at simulator design is making it easier to match the physical and performance characteristics of simulators to the needs of the combat team member.

These breakthroughs have far reaching implications for the field of simulation. For the first time we have the opportunity to attack the premier training problem of the military: How to master the art of warfighting.

WARFIGHTING

Modern warfighting is the most complex activity performed by man. It is rooted in each individual's performance with his single weapon system, support system, logistic system, administrative system, or whatever system he or she must operate as part of the broad machine of combat.

But its scope is far greater. It includes the coordination of that individual's activities with others in the crew, and that crew's interaction with other crews, their interactions with other larger teams of similar combat systems, and the team's interaction with combat support and services support of their own branch and their own service. It includes the interactions of combatants between branches (armor interacting with attack helicopters, for example) and interactions with other services (close air support). On the highest level, it includes cooperating forces of different nations and different languages interacting with each other on a common battlefield.

To be successful at warfighting combatants must master these interactions at all levels. As the implements of war change, the common denominator remains that people have to interact. This is the constant in battle. Training of this is training for teamwork, coordination, execution, orchestration of the battlefield. It is the essence of successful warfighting.

Up to now the United States has relied on field exercises to bring together the component skills needed for warfighting. In sports, these would be called the scrimmages or preseason games which exercise the whole team: the coaching staff, the equipment and conditioning staff, the spotters, the scouts, the front office, as well as the players on the field and on the bench. The need to exercise the whole team distinguishes this from other types of training: Training for team execution requires involvement and practice of the entire team under conditions representative of the contest.

Exercises like the the Army's National Training Center and the Air Force's Red Flag are examples of scrimmages practiced in the military. They are particularly good at creating the chaos that accompanies all large human enterprises, chaos which Clausewitz chose to characterize as the fog of war, the principal determinant of failure.

Yet even as good as these field exercises are, training with real combat equipment on ranges has limitations: Combatants are limited in how far they can push their systems because of safety, participation is limited in duration and frequency because of cost, and hardware is maintained at far better levels than what can be expected a short time into actual war.

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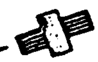
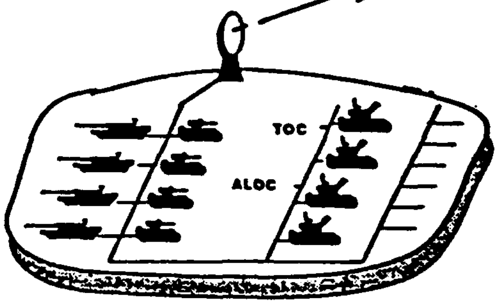
Nonetheless these exercises are valuable. Units learn how to work together under stress, and leaders learn about the dynamics of team operations in chaos.

Further, the resident opponent or aggressor teams at these centers give us insight into the overwhelming importance of practice in the mastery of warfighting: The aggressors have become consummate, cunning warfighters as a result of the thousands of hours of practice they receive during their tour of duty as the threat force. They are formidable opponents. They have mastered warfighting.

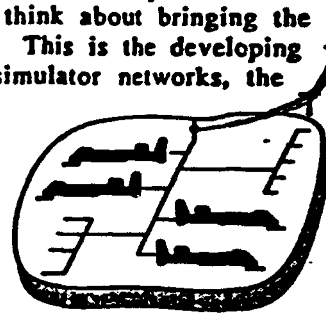
This reinforces what we already know about how teams achieve mastery of their art, be it a sports team, an orchestra, an operating room team or a combat team: Massive amounts of practice is demanded. There is no substitute.





Local Area Network (LAN)
(2 - 200 Simulators)

If the bad news is that to build proficient warfighting teams we have to provide this kind of practice in large amounts with only a small proportion available from the field, then the good news is that recent developments in technology enable us to think about bringing the field into simulation. This is the developing area of large scale simulator networks, the



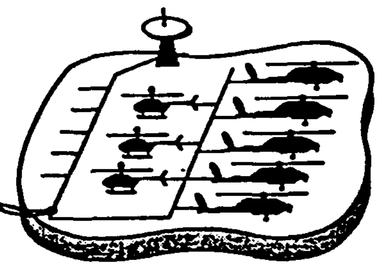
initial work being done in DARPA's SIMNET program (for <u>sim</u>ulator <u>net</u>working) in partnership with the Army and now the Air Force.

WHAT IS IT?

Large scale simulator networking encompasses the local and long haul nets which connect not only combat simulators but also all their command and control, logistics, administration, and other combat support and services support activities. It is a vertical as well as horizontal slice of the battlefield. Because it practices the entire warfighting team in simulation, all those who would fight in a real battle come to netted simulators and combat stations to fight. Both sides.

Combat typically is on real world terrain. Simulators have identical copies of terrain data bases resident in memory and exchange order of battle information via networking. The R&D version of SIMNET now fights on 50km x 50km battlefields, but this will be expanded to battlefields several hundred kilometers on a side in the near future.

The scale of battle is many times greater than what current simulations now enjoy. If R&D progresses at its current rate, networks will be



capable of connecting several hundred combat simulators, command, staff, and support elements in the near future. Several thousand personnel will be involved.

As an example, the SIMNET R&D project is developing test sites of joint airland battle forces. At one such site a tank heavy battalion sized task force will be supported by an aviation company of three scout and five attack helicopters, two elements of air to ground fighters, air defense, fire support vehicles, a scout platoon, a tactical operations center, tactical air control center, forward air controllers, admin/log center (with fuel, ammo, and maintenance vehicles), and artillery and mortars. This totals 44 M1 tanks, 20 M2/3 fighting vehicles, 4 air defense vehicles, 4 fire support vehicles, 8 helicopters, 4 air to ground fighters, and miscellaneous M577 command vehicles, fuel, ammo, and maintenance trucks. These will be fully crewed combat simulators and elements.

This site will be netted to other sites for force-on-force combat. Friendly air support could come from one site, opposing artillery from a second, and reinforcing armor from a third, all fully interactive in real time.

But because of the very nature of networks and those simulators designed for them, the overall network does not have to be fought in one large conglomerate. Networks can be reconfigured into smaller non-interfering clusters of combat fought on different terrain patches under different conditions, all at the same time. As an example, a network of 100 simulators could be fought in one battle (e.g., 50 offense vs. 50 defense, 60 vs. 40, 10 vs. 90, or whatever is called for by the commander organizing the operation) or it cuold be broken down into two exercises (e.g., Battle #1 with 30 vs. 20 and Battle #2 with 25 vs. 25) or any other combination down to the lowest element of 100 separate, non-interfering single vehicle exercises.

These reconfigurations are managed with a microprocessor and take just a few minutes to arrange. Just as combat elements are task organized for a specific mission against a specific threat in real combat, exercises on networks are configured in conference call fashion to meet a specific need.

This dial-a-war way to task organize a network uses the same military chain of command as in combat. Warfighting operations here are the same. Operations orders are issued, forces are assembled, map reconnaissance is conducted, radio frequencies assigned, stores positioned on the terrain, preplanned artillery and air strikes coordinated, and so on. Crews mount their simulators and carry out their missions. Tactical operations centers support the maneuver of the combat elements, coordinate air strikes, and keep track of the battle. Commanders on the field viewing first hand the progress of the battle can be killed forcing new leaders to assume command. For both sides.

Throughout all of this, computers make no decisions about the outcome of warfighting. Computers execute the decisions of the warfighters involved, that is all. People do not fight computers here, people fight people.

CONVERGING TECHNOLOGIES

This advance in simulation is made possible by the very recent convergence of several technologies and innovative applications.

Computer Networking

First characterized by the ARPANET packet switching network, local area networking technology (LAN) has matured into off the shelf, standardized products. Packet switching protocols provide the means for transmitting data units needed by netted simulators and other gaming stations. Long haul networking (LHN) using wideband satellite or land lines, particularly the new capabilities being created with fiber optics, provide interfaces between LANs via gateways.

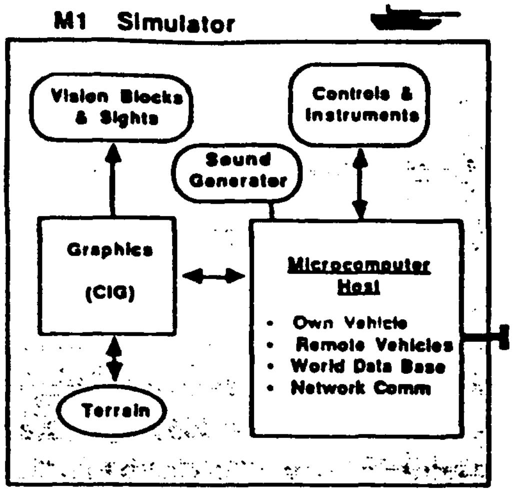
Communications

The communications capacity for running networks is expanding rapidly. C band wideband satellite capabilities are moving to Ku band with reduced cost and size. Fiber optic land lines, including those to Europe, are proliferating at a rapid rate. Whereas previously point to point connection schemes predominated, a variety of hybrid, reconfigurable schemes such as those featuring land lines that feed regional satellite uplinks broadcasting back to each site equipped with small receiver antennae are now discussed routinely. Self routing and self healing interconnections between sites are transparent to users.

Distributed Computing Architecture

There are many ways to structure computing resources on a LAN. The one that has worked the best so far is a completely distributed computing architecture where nearly all computing power resides in the simulators on the net. No mainframe or centralized computers are employed in an executive control or major computational role. As each simulator is plugged into the network, it brings the extra computing power needed to conduct network business given the network's larger size. No additional processors are needed.

Each simulator is a self-contained stand alone entity with its own host microprocessor, graphics, sound system, a complete copy of the terrain data base, and whatever else is needed to create a bubble of synthetic reality for its crew. This is similar to current simulator architectures except that each simulator host processor also has a fully functioning network



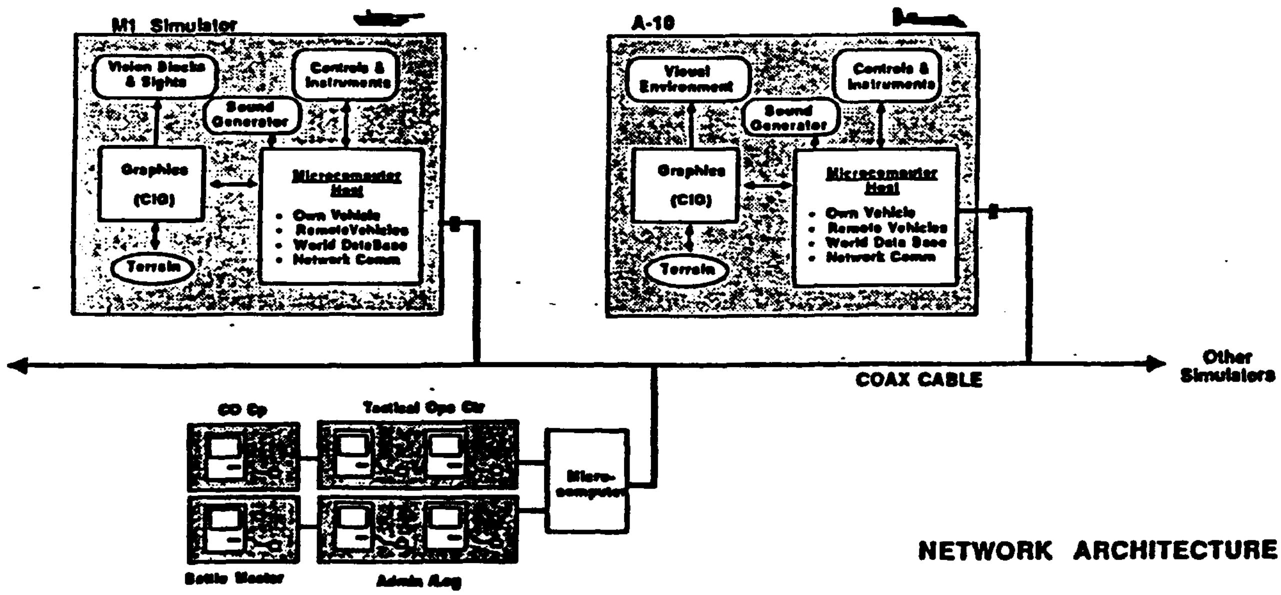
SINGLE SIMULATOR ARCHITECTURE

communications module which can transmit and receive messages. Simulators plug together via cable, transmitting and receiving data units from other simulators and gaming stations. When a simulator fails, the rest of the network continues minus the contributions of the failed device. Network degradations are soft and graceful.

Because each simulator is designed to be stand alone, specifically to be able to generate a complete set of cues to its crew without help from external processors, it can maintain a credible world for its crew should network transmissions suffer momentary interruptions. First, only a small amount of information is sent between simulators consisting mostly of orientation and position information (coordinates) and unique events ("I am simulator #16 and I have just hit simulator #22 with a round of SABOT in his left engine compartment." "I am simulator #22, I have just suffered a catastrophic kill, and I am now a burning hulk at coordinates ES89028876."). Second, each simulator is able to maintain predictive models about all other simulators on the network based upon the latest data packets from those simulators. If an update is slow in coming from another simulator, then its state can be inferred. When a new update is received, the actual state data is used in the next frame. If there is a serious discontinuity between the self generated inference and the newly received data message, algorithms can be activated to create a credible transition into the current state.

Network traffic using a distributed computing architecture turns out to be surprisingly modest. The need for message conflict resolution, the problem of senders and receivers of message packets all wanting to use the network at the same time, is minimized.

Also minimized is the problem of data corruption, another worrisome issue in networking. While every effort is made for pure data transmission, it is a lesser problem here for several reasons. There are relatively few message types and of these only a few are of such importance that they need acknowledgement by the *recipient(s)*. Most messages are updates and are transitory: The next update is close behind. Since there is enough local processing power at each recipient to double check the



NETWORK ARCHITECTURE

credibility of an update, messages suspected of being bad can be discarded. Finally, if desired, network transactions can be allowed to mirror the dirtiness of chaotic operations in the real world. Ambiguity, error, and confusion are all properties of war and an occasional corrupted data element fits right in.

But perhaps the most important attribute of a distributed computing architecture is that it is an architecture for growth. Networks are the skeletons, microprocessors are the muscle, and communication protocols connect the two. As new, more powerful, cheaper microprocessors become available, they are simply plugged into the network. Outdated microprocessors are thrown away. As with the ARPANET, scores of different types of microprocessors using dissimilar operating systems can all talk via common network protocols.

This architecture allows anyone with a microprocessor to connect onto the net, either stand alone or as part of a simulator. A smart individual, armed with a microprocessor, can develop creative ideas off line and implement them on the net. The architecture is open and non-proprietary.

Simulator Design

There are many approaches to designing simulators, some which begin with physical models of the world and others which begin with behavioral or cue driven models of the world. In the first case, fidelity is defined by the match between the simulator's characteristics and a particular set of measurements from the physical world. In the second case, fidelity is defined by the strength and effectiveness of the cues which the simulator delivers to the operator, cues of specific information tailored to who the operator is and what he is doing in the simulator.

The attraction of the behavioral approach is that it can lead to the same results as the physical model but it is not held captive by it. Using the concept of selective fidelity, simulator and simulation characteristics which contribute directly to the goal of the training are represented in high fidelity, and those which do not contribute to the training are in low fidelity or not included at all.

Further, this approach recognizes the legitimacy of departing from the fidelity curve, including the use of exaggerations and fictions when they do not compromise the training goal. It also leads to the application of a rule taken from the discipline of industrial design: Do not make something appear to be what it isn't if broken expectations can be damaging.

Special Effects

Advances in sound synthesization, projection of infra sound, and application of design concepts from the special effects community have been used successfully to complement other traditional simulator cuing subsystems. Since simulations are illusions, the illusory technologies can enhance the end effect of a cue. Microprocessor based delivery systems make this affordable.

Graphics

The fast paced progress in microprocessors, integrated circuit design, and mathematical algorithms is nurturing advances in real time graphics. In almost all cases, the price for comparable performance is dropping dramatically. Further, the methods by which these machines render images are different than in the past making earlier measures of merit less valid. When coupled with selective fidelity cuing, the result is a new and powerful generation of graphic subsystems.

The use of selective fidelity has lead to an important new concept in graphics dealing with the relationship between environmental complexity in a scene and the display complexity used to present the scene. The predominate trend to date in computer image generation has been towards low environmental complexity (sparse data bases with minimal or no texture, few moving models, and modest correlation with specific topographic locations) and high display complexity (high screen resolution and high frame update rates). Data bases are costly to construct, few in number, difficult to modify, and machine specific. Cost of the CIGs has been high.

The graphics machine designed for warfighting in SIMNET reverses this trend. It is high in environmental complexity (many moving models and special effects, dense topological features with texture) and low in display complexity (relatively low numbers of pixels and an update rate of 15 frames per second for its eight channels). It is also very low in cost. The interesting functional phenomenon is that fighters viewing the combat world concentrate on its complexity, the only part that is tactically relevant, and adapt to its low resolution as they would a mud speckled window.

Rapid Prototyping R&D Process

Along with the evolution of these technologies comes a rigorous style of development characterized by what SIMNET calls the *60 % Solution* . This model recognizes the transient nature of any particular technology and the danger of freezing progress at a given technological plateau. It uses rapid prototyping to iterate on a specific technological solution but never tries to solve 100% of any problem at any time. This applies even if there is committee consensus about what the 100% solution is as articulated in a fully staffed and approved specification.

The 60% Solution closes on the goal, continually redefining and refining the objective, constructs prototypes and mock ups as interim byproducts to verify direction, and cleans up the mess later. Best commercial practices replace mil-spec design philosophies.

The concept is that in a changing technological world, managing change is the *principal* role of the R&D process, not producing specific products. The 60% Solution is how SIMNET has responded to the Packard Commission recommendations.

HOW IS THIS DIFFERENT?

The inherent nature of networking gives rise to different ways to think about simulation. Some examples are below.

A Simulated World vs. a Single Simulator

Networking creates a simulated world. Combatants enter that world through their simulators or gaming stations, traverse that world, fight in that world, and are supported in that world by combat support and services support (e.g., refueling, rearming, and resupplying). Architecturally, like a piece of a hologram, as long as at least one microprocessor is living on the net and hosts a copy of the data base, the world lives....when other simulators join the network, their copies of the world are updated and their crews enter the current world.

As with other simulations, the simulated world is rent free, sustains no permanent ecological damage, and allows commanders to push their weapons, tactics, and organizations to the limit. The principal difference is the scale: Most simulators focus on the single crew. Networking creates a world of large forces.

This is a profound departure from simulation as we know it today. The foremost concern of every combatant is how to survive, fight, and win in this world. His simulator or gaming station is not an end in itself, inspected and certified for its micro-fidelity against a piece of hardware. The simulator is simply the entry device into the world, Alice's looking glass, and as long as it maintains a modest level of representativeness and does not perform in any obviously dumb manner, then the combatant takes it for what it is: The piece of equipment which he must adapt to in order to fight and win.

This is consistent with combat. Rarely does actual equipment perfectly match a manufacturer's engineering specification. Nor will weapon systems in combat perform like they do with good maintenance on sterile ranges with unstressed organizations in peacetime. An experienced commander knows this. He expects differences and organizes training programs to prepare for them. He understands that the hidden weapon in combat is the adaptable, creative, motivated man who can assess the characteristics of a combat world, determine what is needed to win, and make it happen with whatever hardware he can get his hands on, fix, modify, jury-rig, or whatever.

To date, the predominate thrust in simulation has been *inside* the single weapon system. Networking changes this. It creates a 24 hour, 7 days a week, "We Never Close" world where the predominate thrust is *outside* the single weapon system into the world of warfighting.

Experienced Teams vs. Novices

Because networking allows large teams to engage, the greatest benefit derives from the warfighting of combat personnel in operational units. These personnel have already developed their individual skills: Drivers know how to drive, pilots know how to fly, gunners know how to engage and kill targets. Networking allows them to bring the warfighting team together and practice the integration of these skills.

This is not to suggest that lesser skilled students cannot benefit from being inserted into a combat world for training. The efficiency of simulation, coupled with the ability to tailor particular environments, makes this well suited for the institution. One can imagine recreating the great tactical battles of military history with students inserted into the battle interacting with the eventual outcome.

Rehearsal on a specific piece of terrain in the simulator might well raise the floor of proficiency for students so that subsequent exercises on that real terrain yields greater learning.

No Reset Button

In today's typical simulator session, the instructor usually initializes the simulator into a particular configuration and then conducts the training aimed at a given syllabus objective. Upon the conclusion of the session, or perhaps during the session, the instructor resets the simulator to various other conditions. This is efficient when training individual skills, but in continual combat operations where the crew is warfighting in a simulated world with other team mates, reset is a foreign concept.

When a combat vehicle runs low on gas, the crew must arrange to be refueled from a fuel truck, coordinating rendezvous, amount of fuel needed, protection from hostile forces, and rejoining the battle. When the supply in the fuel truck is too low to top off each vehicle, commanders must decide how they will modify their combat plans to accommodate this situation. The crew cannot just jump out of the simulator and press a reset button to get well again.

At first, this might seem to add inefficiency into training sessions. If these were traditional training sessions, then this would be so. When a crew goes off in the wrong direction during a maneuver, the tendency is to stop the maneuver, instruct the crew on their error, and begin again.

However, in the real world crews often make mistakes. It is part of the fog of war. Making mistakes and assessing and correcting these through the chain of command in the dynamics of warfighting is a rich form of trial and error learning. In combat, leadership includes being an assessor of performance and a remediator of the forces under command.

No Instructors, Controllers, or Umpires

In networked warfighting the combat team engages its opponent just as it would in the real world. This means that the chain of command on each side controls the battle to the best of its ability, issues operations orders, receives spot reports, maneuvers on the battlefield, and fights. Commanders trying to survey the battlefield can be killed and the chain must react and replace. Just as in combat, there are no overlords in this type of exercise other than the chain of command. None are necessary. Mentoring is the agent of improvement in leadership skills.

After Action Reviews Performed as in Combat

As above, the chain of command performs after action reviews as they would in combat. Even though networking allows for the collection of perfect knowledge about what each member of any conflict is doing at every moment of the battle, the only relevant information which the team requires is the same information it would have in combat. The combat model dominates training.

Real Time Casualty/Kill Removal

Just as commanders must pay greater attention to logistics, administrative, planning and execution factors when operating in a long term interactive world, there are similar concerns when crews who are injured or killed as a result of hostile action or accident must be immediately attended to or removed from the simulation. In both cases, the tactical situation can change drastically because of the reduction in force strength as well as the attendant burden of having to care for the injured, service damaged vehicles, call for personnel replacements, and insert them at the right time and place in the battle.

WHAT DOES THIS ALLOW US TO DO DIFFERENTLY?

Training - Fight the Present

Large scale simulator networking has obvious implications for training warfighting teams to a level of mastery never before seen outside of actual combat. Rapid train up of reserve forces, proficiency injections for new units or those marginally capable, and Olympic training for those units already judged to be on top but which would like to go higher, are areas which might be possible with this new technology.

Future networks appear to be growable to sizes which could match the largest organizational structure, an attribute which is understood when one compares the similarity of the layered levels of combat organizations with nested networks. Just as the maneuver sectors of several battalions can be encompassed by the sector of an artillery battery, and several of these can be encompassed by the area covered by an aircraft, so too, one giant network or several nested interconnected networks can create the same world in simulation. If trends continue, it is likely that theater level exercises could be conducted in networked simulators in the mid term.

By 1988 R&D networks should be operational which can accommodate several hundred personnel. By 1990 that will expand to a few thousand. Commanders world wide, including Allied commanders, will have the ability to dial up training exercises to practice joint warfighting skills in a garrison setting.

This elevates simulator networking to a strategic level. It becomes a technology which offers new alternatives for the strategic positioning of U.S. forces world wide.

Configuration allows force-on-force training. Professional fighting forces compete vigorously when opposing each other. This is not true when fighting a computer. Video games become tiring. Networked combat derives its motivation from force-on-force ego invested competition. Coupled with the efficiency of large exercises conducted in networks, greater and greater garrison time can be involved in warfighting. Units can always be at war.

Networks can also provide access of the school house institutions to units for the delivery of new instructional material and technology, and in turn for feedback as to the effectiveness of training. Networks can serve many purposes in preparing our forces.

When the data base is of a crisis area and the order of battle reflects the latest intelligence, the coordination of team operations can be practiced in networked simulators. This is most critical. Many special situations in recent memory could have benefited from additional opportunity to practice teamwork under demand conditions. Since networks are easy to set up, it is possible to conduct dress rehearsal and contingency planning en route to the scene (e.g., shipboard) or nearby the crisis area

Because combatants view their simulators as entry devices into a warfighting world, they have less tendency to distinguish between simulator failures and simulated failures. In both cases, their warfighting equipment and environment has been altered. In response, they adapt and fight on. This has implications for the rigor with which these simulators are maintained possibly resulting in cost savings.

The interesting by-product of networked exercises is that they exercise the chain of command in every respect. The chain of command must organize and supervise the use of networks as well as the warfighting that goes on inside of them. Leaders are trained at every juncture and practice what they have learned.

Development - Fight the Future

Team simulation introduces a new tool for the development of weapon systems. This is made possible because the simulators can be employed in simulated combat with the same force size and tactics expected of the candidate system against base line systems (other networked simulators) representing the expected threat and manned by aggressors trained in the tactics of the opponent. This expands and complements the design data collected in engineering simulators at Service and contractor R&D centers.

Industrial and university centers can have small networks on which to do their research and development. As ideas and designs mature, these laboratories can be netted to the larger world for test. Challenge matches can be arranged and designs tested in the caldron of battle.

When typical troops are used in this context, training and tactics have to be addressed early in the development cycle. Prototype training systems must be developed to prepare the troops to use the candidate systems. Potential problems in training, human factors, manning, organization, and implementable tactics are discovered early on.

For those good ideas and designs which rise to the top, the developer has a rich environment in which to show them off: The audience dons combat gear, enters the simulated world, and warfights in the candidate weapon system against the threat. Instead of communicating with thick proposals or lengthy briefings, government officials and legislators can live the weapon system in combat conditions.

If it is decided to go forth with full scale development of the weapon system, the training subsystem, including the training simulators, are already developed. The training system can be fielded before the fielding of the weapon system as it should but rarely is.

This use of the networked world as a theater applies to demonstrations of U.S. weapons which are being considered for foreign military sales as well.

Testing and Cost Projections

The testing requirements for new weapon systems are rigorous but often can only be accomplished under restrictive conditions, e.g., safety constraints that limit realistic maneuver, use a small number of early test vehicles unrepresentative of actual employment strength, and do not employ the system as a fightable weapon adapted by its operators to changing conditions to maximize strengths. On the other hand, team simulation is not limited by these constraints and can complement testing by providing data in these areas.

Similarly, cost projections of life cycle costs often make many assumptions about how typical forces will use the system. Data from interactive simulations where typical combatants fight the candidate systems against base line forces can augment cost models.

Future Command and Control Systems

One far reaching and less obvious attribute of simulator networking is that it is a mimic of future command and control structures. A joint AIRLAND battle of multi-battalion size with air, land, command, and support elements networked between several sites by long haul networking is, in effect, a real time, sophisticated command and control system. As the simulator networking technology is developed to allow this level of exercising there is a direct advance in the state of command and control systems.

In the same sense, networks that span Allied forces for NATO exercises are at the heart of interoperability. Networks which can be successfully constructed across these boundaries will aid in the solution of interoperability issues.

WHERE ARE WE GOING?

Ongoing R&D on large scale simulator networking will have several influences on the course of simulation. Some likely trends are suggested below.

International Nets

The international networking infrastructure for world wide simulator networks will grow over the next several years. Digital communication capacity will support this at low cost. Networks will be connected for large exercises when needed, or be operated in smaller clusters for local use.

Networkable Simulators

To get the maximum use of these networks, DoD will likely require that all simulators procured in the future are network capable. The importance of mastering warfighting is a foremost military need, and this is an important step to provide this capability. All networks will be standardized by DoD and will be interconnectable.

Common Cues

The major technical issue will be how to construct functionally equivalent data bases, specifically the equivalence in cues provided to crews operating in the same world but in different types/manufacturers' simulators. This will be aggravated by the pace of technology. We can expect to see many different generations and types of simulators residing on a given network just as many different styles and ages of telephones are plugged into the telephone system. The increased capability of newer simulators must be compatible with the capabilities of earlier generation machines. A newer simulator cannot be allowed to give its crew an artificial, unearned, unfair tactical advantage.

Affordability

Because of the numbers of simulators which will be needed for large team practice across the U.S. and NATO networks, the unit cost of new simulators must be dramatically lower than simulators today. Work ongoing in this area has demonstrated that this is possible and in fact is desirable given the pace of the core technologies. With technology moving so quickly, investing heavily at a given technology level has severe penalties. The concept of an objective, finished system ready for long term procurement belies the technological realities of today's world. Low cost systems which have paid for themselves and can be removed from service after five years capitalize on technological advancement and keep simulation on the cutting edge. This argues for a process based upon best commercial practices (non-mil-spec) and a very restrained logistic infrastructure.

Look To The Outside

The dominate orientation for simulator designers should be to the warfighting world outside the simulator, not inside. For those life or death battles in which the combatant has fully projected himself, the effort and money that goes into micro-fidelity has little return. It is the interaction of the individual and his crew with the world outside which deserves the highest attention to fidelity.

60% Solution

All of the above argues for an R&D approach which uses the 60% Solution: Develop quickly, be satisfied with good enough, keep the development cost and recurring costs low, and plan to throw away earlier than in the past. To keep pace with this approach, the requirements process from Service users will have to allow rapid, iterative development and fielding of less than perfect devices. In the end, however, this process will provide superior solutions to the user for less money.

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